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THE WITWATERSRAND SYSTEM

IN THE

KLERKSDORP-VENTERSDORP AREA

A PRELIMINARY REPORT

By

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ERRATA.

Table of Contents.—Lines 22 and 24: For "Old" read "old".
Page 7, Line 48: For "thurst-faulting" read "thrust-faulting".
Line 49: For "Witwatersiand" read "Witwatersrand".
,, 9, Line 32: For "Estates" read "Estate".
,, 11, "Fig. 3" should be read as at bottom of page.
,, 18, Line 4: For "correspondens" read "corresponds".
,, 21, Line 2: For "Figs." read "figures".
,, 23, Line 16: For "page 22" read "page 20".
,, 24, Line 29: For "or carbon" read "of carbon".
,, 28, Line 29: For "voclanic" read "volcanic".
,, 30, Line 7: For "conglomerates" read "conglomerate".
,, 31, Line 16: For "page 30" read "page 12".

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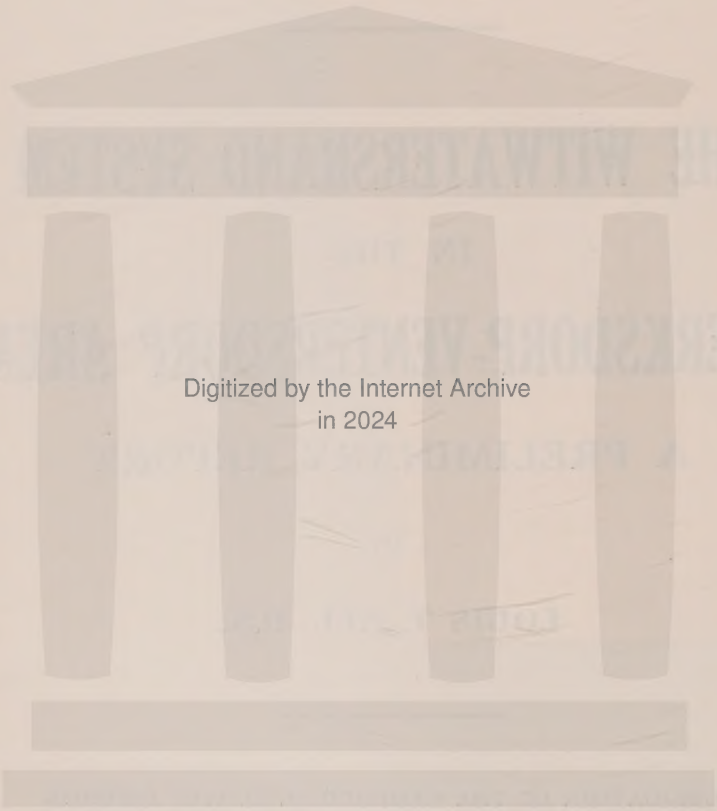


CONTENTS.

PAGE

INTRODUCTION 5

MAIN STRUCTURAL FEATURES 5

Relation of the Witwatersrand System to the Old Granite 6

Relation of the Witwatersrand System to the Ventersdorp System 6

Structure of the Witwatersrand System 7

Step-faulting between Klerksdorp and Ventersdorp 7

Possible thrust-faulting to the north of Klerksdorp 7

Faulting on Buffelsdoorn No. 58 and the Klerksdorp Commonage 8

Structure of the Afrikander-Rietkuil Neighbourhood 13

Summary 15

GENERAL ACCOUNT AND CORRELATION OF THE WITWATERSRAND SYSTEM 16

The Hospital Hill Series 17

Basal Volcanic Rocks 18

The Orange Grove Quartzites 18

The Water Tower Slates 18

The Contorted Bed 18

The Speckled Bed 19

The Hospital Hill Quartzites 19

The Government Reef Series 19

The Tillite 22

The Buffelsdoorn Reef 24

The Reef of the Old Pope's Mine 24

The Afrikander-Rietkuil Reef Zone 24

The Reef of the Old Elandslaagte Mine 26

The Jeppestown Series 26

The Upper Division of the Witwatersrand System 27

The South-easterly dipping quartzites 27

An interbedded lava sheet 28

The Ada May Reefs 28

The Commonage Reef 29

The Westerly Dipping Quartzites 29

The Gold Estate Reef 29

Correlation of the Quartzites on the Commonage 30

Summary and Correlation of Reefs 31

Ventersdorp and Witwatersrand Systems are exposed. The Black Reef Series, which forms the base of the Transvaal System, is entirely unconformable to all these rocks.

Relation of the Witwatersrand System to the Old Granite.

In the Klerksdorp-Ventersdorp area the Old Granite, as in the Rand, Heidelberg and Vredefort areas, forms the basement rock upon which the Witwatersrand beds rest. There are many instances, especially to the west and south-west of Ventersdorp, of the Old Granite lying across the strike of Witwatersrand beds or even surrounding them, but such occurrences are always the result of faulting. Evidence for an intrusive relationship between the Old Granite and the Witwatersrand System such as granite veins or apophyses penetrating the strata, contact metamorphism of the sediments, or the presence of basic or other differentiated phases or fine-grained selvages in the granite along the contact could not be found.

Relationship of the Witwatersrand System to the Ventersdorp System.

The Ventersdorp System in this district embraces a group of volcanic rocks such as lavas, quartz-porphyries, agglomerates, breccias, tuffs and dark siliceous flagstones and shales. These rocks occupy wide stretches of country and except for local complications, they lie nearly flat, or are gently folded. While south of the Rand and in the Heidelberg and Vredefort areas there is an apparent conformable succession from the Witwatersrand beds up into the Ventersdorp volcanic rocks, the mapping of the Klerksdorp-Ventersdorp area has revealed the presence there of a marked unconformity at the base of the Ventersdorp System. Ventersdorp rocks can be found resting on any of the various horizons of the Witwatersrand System exposed; they even extend right across on to the Old Granite. Further, the presence sometimes of Ventersdorp rocks between ridges of Witwatersrand beds, and the rough contouring of the slopes of a hill built of Orange Grove quartzites and shales by an amygdaloidal lava on Doornfontein No. 96 prove that the Ventersdorp beds were deposited on a surface of older formations that had a fair amount of relief. As a result of this relation between the earlier and later formations the Witwatersrand rocks and the Old Granite occur as a number of large and small inliers in the Ventersdorp beds. Where the old formations are concealed overlying Ventersdorp beds may be anything from a few feet to well over a thousand feet thick.

There are occurrences, of course, where Witwatersrand and Ventersdorp beds were brought against one another by faulting. A dip fault, for example, is responsible for Witwatersrand beds butting into Ventersdorp amygdaloid on Tweelingsfontein No. 46, while on Buffelsdoorn No. 58, Welgegund No. 38, and Palmietfontein No. 29 a strike fault terminates the Buffelsdoorn Reef quartzite in turn against amygdaloidal lava, agglomerate and quartz porphyry.

The relation of the Ventersdorp to the Witwatersrand System and the deposition of the former on an old land surface of marked relief, are factors of great importance in the search for those horizons known on the Rand in the concealed bodies of Witwatersrand beds around Klerksdorp.

Structure of the Witwatersrand System.

In the various exposures of the Witwatersrand System the trend of the strata is mainly in a N.E.–S.W. direction. The dip is usually to the south-east averaging about 30 degrees, except locally where the strata are much dislocated, bent or overtilted. There is much evidence to show that the formation was subjected to repeated pressure and tensional forces over a long period of time which produced folding and dislocation of the strata in the form of many normal and reversed or overthrust faults. Dislocations of the Witwatersrand System started in pre-Ventersdorp times and were renewed at intervals until after the deposition of the Black Reef and Dolomite Series which are also folded and faulted but generally in a minor degree. In some localities, of which the Afrikander-Rietkuil neighbourhood is a good example, where all or several of these recurrent crustal movements affected the Witwatersrand beds, a most complicated structure has resulted.

Step-faulting between Klerksdorp and Ventersdorp.—The disturbances that affected the Witwatersrand strata most appear to have taken place just prior to and during Ventersdorp times, and to have produced a number of prominent N.E.–S.W. trending strike or oblique faults as well as dip-faults with a general N.W.–S.E. trend; and it seems very likely that the great Ventersdorp volcanic eruptions followed or were correlated with these fissures (see Fig. 1). In this connection the general distribution of the volcanic agglomerates and boulder beds, rock types that could not have been formed far from the source of their constituents, along or close to some of these lines of fracture is significant. As seen from Fig. 1 these strike and oblique faults traverse both the Witwatersrand System and the Old Granite and are responsible for several reduplications of the rocks across a wide stretch of country. Over the distance of thirteen miles covered by Fig. 1, for example, strata belonging to the Hospital Hill Series of the Witwatersrand System are repeated no less than seven times to disappear eventually underneath a cover of later Ventersdorp and Transvaal rocks. These repetitions of Lower Witwatersrand beds are responsible for the fact that strata later than the topmost beds of the Government Reef or possibly the lowermost beds of the Jeppestown Series are not exposed in the Klerksdorp-Ventersdorp area with the exception of the quartzites and conglomerates cropping out on the Klerksdorp Commonage which presumably belong to the Upper Witwatersrand division. The presence of an Old Granite inlier in the Dolomite on Katdoornbosch No. 127, six and a half miles east of the nearest exposures of Rand beds indicates the continuance of faulting of this type underneath the cover of the Black Reef and Dolomite formations. These series of more or less parallel faults thus have all the characteristics of step-faulting with the downthrow sides west of the lines of fracture.

Possible thurst-faulting to the north of Klerksdorp.—In that belt of Witwatersiand beds which extends south-westwards to the vicinity of Klerksdorp the strata show the usual south-easterly dip, but on the southern part of Goedgevonden No. 20 the lower-most beds of the Witwatersrand System, i.e. the Orange Grove quartzites,

followed in turn southwards by successively higher beds of the Hospital Hill Series, become first steeply inclined and then overtilted, so that on Palmietfontein No. 23 and the greater part of Rheebokfontein No. 37 the dip is in the reverse direction. Incidentally the Orange Grove quartzites become very broken and shattered and in places disappear completely, either by passing underneath or by being cut out against the adjacent Ventersdorp volcanic agglomerate. Higher up in the succession of Lower Witwatersrand beds, still dipping to the south-east, first the shale at the base of the Government Reef Series and then increasing portions of the quartzites above and below it start to disappear until on the northern boundary of Elandsheuvel No. 54 a thousand and more feet of sediments are missing at the surface. Lastly, on Palmietfontein No. 29 the strata constituting the upper section of the Government Reef Series bend away abruptly from their normal south-westerly strike to trend in a more westerly direction towards the south-eastern corner of Rheebokfontein No. 37 and the adjoining north-eastern corner of Elandsfontein No. 54. On the adjoining parts of the Palmietfontein, Rheebokfontein and Elandsheuvel the strata therefore became pressed into much narrower confines and in the adjustments that followed beds of higher horizons, like the topmost quartzite (Buffelsdoorn Reef quartzite) of the Government Reef Series, for example, in the south-east corner of Rheebokfontein, were pushed across lower. The inversion of the lowermost Witwatersrand beds and the general convergence of the strata south-westwards into narrower limits do not appear to have been brought about during a single phase of crustal dislocation with forces acting in one direction only. It seems rather that there were two periods of pressure followed by overthrusting, the one much later than the other. In the first, pressure was applied from the west or north-west and was responsible for the overtilting of the basal members of the Witwatersrand System. During the second period pressure acted from the south-east to the north-west and pushed some of the higher beds across the lower. The elimination of strata, on the other hand, along the contact of the Hospital Hill and Government Reef Series is probably due to a hinged fault which originated during an interval of relief or tension in the earth's crust. A little further south, on the eastern part of Elandsheuvel beds belonging to the lower section of the Government Reef Series lie only about four to five hundred yards west of Upper Witwatersrand quartzites, considered to be Elsburg quartzites. A fault of some magnitude, therefore, must separate them, probably also a thrust fault; but the presence of transverse faults in the Lower Witwatersrand beds and the lack of outcrops between the exposed rocks make the structure there very complicated and difficult to decipher.

Faulting on Buffelsdoorn No. 58 and the Klerksdorp Commonage.—In the course of mapping over Buffelsdoorn, Palmietfontein and the Klerksdorp Commonage the presence of one or more faults trending in a direction similar to the step-faults described above but with a downthrow to the east, was revealed. On Buffelsdoorn No. 58 and Welgegund No. 38 the fault follows the strike of the Witwatersrand beds closely and it is responsible for the termination of the Buffelsdoorn Reef against Ventersdorp rocks. That the position of the Ventersdorp against the Witwatersrand System there is due to faulting and not the usual unconformable relationship is

indicated by the disturbed character of the rocks along the contact and the termination in succession of a volcanic agglomerate, lava and quartz porphyry against the Buffelsdoorn Reef quartzite or the remnants of a shale body immediately above it. Its course further southwards across Palmietfontein No. 29 is not so clearly defined owing to lack of continuous outcrops, but the disturbed character of the beds and their dislocation near some old shafts in the centre of the farm seem to indicate that some of the faulting there represents an extension of the same break. Much surface drift also obscures its northerly extension. In this direction between Rietfontein No. 78 and Rietkuil No. 99 Ventersdorp amygdaloid gradually comes to lie against lower and lower horizons in the Witwatersrand System, so that the Buffelsdoorn break, if it does persist along the contact of the two formations, becomes an oblique fault. It seems to die out, however, for the Ventersdorp lava to assume its usual unconformable relationship to the Witwatersrand beds.

On the Klerksdorp Commonage there are two patches or inliers of Witwatersrand quartzites separated from one another by Ventersdorp lavas. The larger of the two is just east of the Klerksdorp railway station and extends northwards into Elandsheuvel No. 54, while the other is about two miles east of the station. As shown in Figs. 2 and 3 these inliers represent a reduplication of the same beds by an oblique fault. In both inliers there are two quartzites, the one unconformable to the other. The general strike of the lower quartzite is in a north-east by north direction. Owing to a certain degree of folding, there are variations in the angle and direction of the dip, but mostly, however, the dip is towards a south-easterly direction at an average angle of about 20 degrees. The strike of the upper group is north by east with a 20 to 40 degrees westerly dip. This contrast in the disposition of the two quartzites is further enhanced by the presence of a large pebble conglomerate, the " Gold Estates Reef ", at the base of the upper quartzite. The angular unconformity between the two quartzites is clearly revealed close to the railway-crossing just south of the main road in a disused railway cutting leading to an old quarry on the hill nearby, in some prospecting trenches and pits east of the Klerksdorp trigonometrical beacon and on the kopje to the north of the old Niekerk's mine, besides in many other old prospect workings where the Gold Estate reef was opened up. The extent or magnitude of the unconformity, however, is difficult to estimate owing to limited exposures. Until Jorissen * drew attention to the presence of this unconformity the tendency was to explain the opposite dips of the quartzite beds as the result of anticlinal folds. The true relationship of the two quartzites to one another and their displacement by faults are shown in Figs. 2 and 3.

It was very difficult to decide the nature of the contacts of these quartzites with the Ventersdorp lavas, especially as the contact or rocks in the immediate vicinity are rarely exposed, and to know whether a fault, an unconformity, or even a conformable sequence is indicated. Take the junction of the lava with the westerly dipping quartzite, for example. In some localities a dark gritty or pebbly rock was noticed at, or very close to, the contact and its presence

* Jorissen, E. " Structural and Stratigraphical Notes on the Klerksdorp District, with special reference to the Unconformity beneath the Elsburg Series." Trans. Geol. Soc. of S.A. Vol. IX, 1906, pp. 40-52.

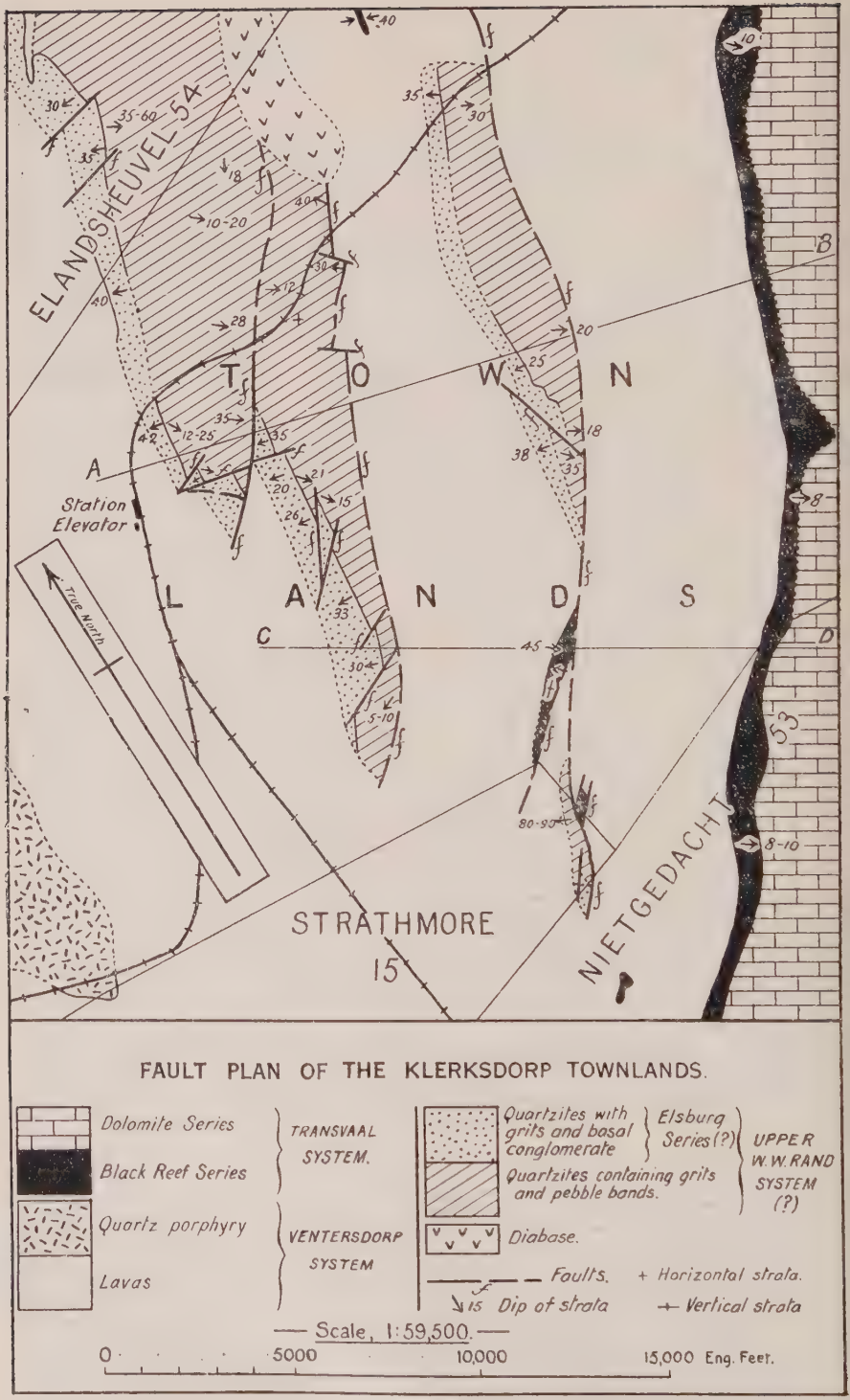
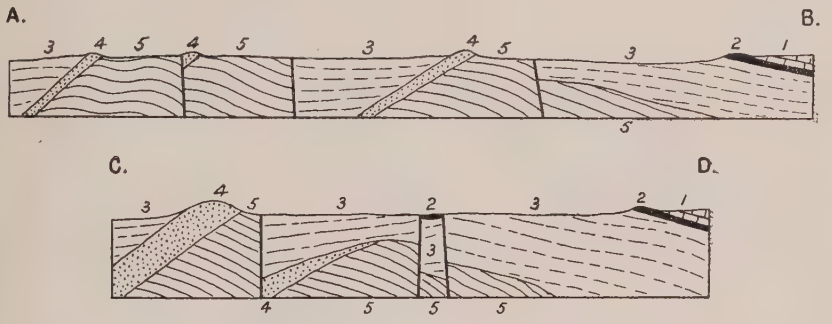
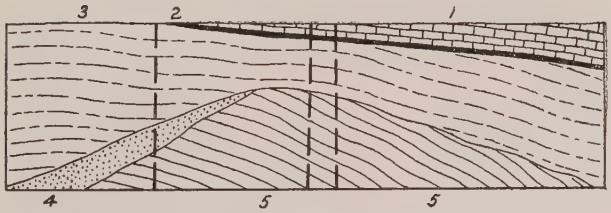

ELANDSHEUVEL 54
TOWNLANDS
STRATHMORE
15
NIETGEDACHT
53
Station Elevator
True North
A
B
C
D
FAULT PLAN OF THE KLERKSDORP TOWNLANDS.
Dolomite Series
Black Reef Series
Quartz porphyry
Lavas
TRANSVAAL SYSTEM.
VENTERSDORP SYSTEM
Quartzites with grits and basal conglomerate
Quartzites containing grits and pebble bands.
Elsburg Series(?)
UPPER W.W.RAND SYSTEM (?)
Diabase.
Faults.
+ Horizontal strata.
Dip of strata
Vertical strata
Scale, 1:59,500.
0
5000
10,000
15,000 Eng. Feet.

FIG 2.

there, as will be shown subsequently, may be an important clue indicating a conformable passage from the one formation into the other. It may represent a transition in which the deposition of ordinary sediment changed over into that of volcanic matter when the underlying rocks were still unconsolidated, much less tilted. Yet further to the north-east on Rietkuil No. 99 a grit similar in every



Sections AB and CD—See Fig. 2.



Ideal Section of CD showing relationship between formations before faulting.

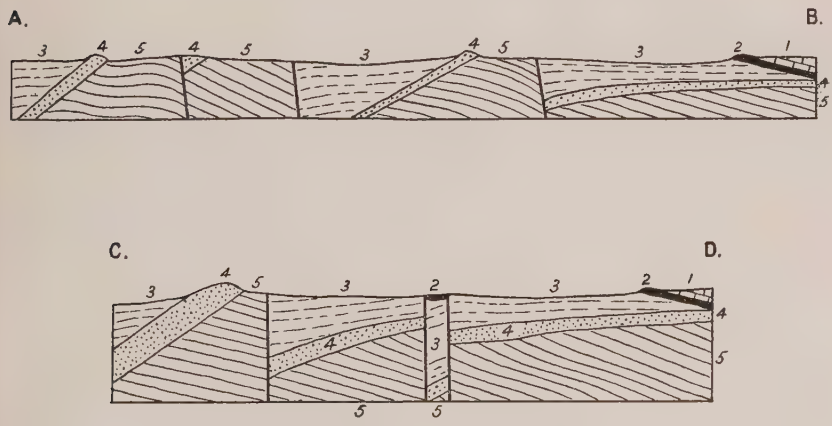


Fig. 3.

Sections AB and CD—See Fig. 2.
Alternate interpretations:

1. Dolomite Series ... ... } Transvaal
2. Black Reef Series ... ... } System.
3. Lavas ... ... Ventersdorp System.
4. Quartzites with grits and basal conglomerate } Elsburg Series (?) } Upper Witwatersrand
5. Quartzites containing grits and pebble bands } System (?)

respect to that of the Klerksdorp Commonage and to those found in the passage beds on the Rand and in the Heidelberg district, where the relation of the Elsburg quartzite to the Ventersdorp lava is essentially that of a conformable sequence, was found resting on the dip slopes of the uppermost Hospital Hill quartzite. It is only a few inches thick and is overlain by a narrow strip of ashy rock which in turn is followed by the Ventersdorp amygdaloid. The volcanic rocks appear to dip to the south-east at the same angle as that of the quartzite beneath them which would lead one to suppose that the lava and quartzite are conformable whereas actually this is not the case. The explanation probably is that the first particles of volcanic matter to be deposited against the slopes of early Rand quartzite ridges mingled with the loose sand, grit or pebbles lying on the surface and subsequently consolidated into dark grits or conglomerates like those found in the passage beds mentioned above. It is very likely that the dark gritty rocks on the Klerksdorp Commonage originated in a similar manner. The westerly dipping quartzite appears to pass conformably underneath the amygdaloidal lava, but actually the wide stretch of Ventersdorp beds, which separates this quartzite from the folded Witwatersrand beds on Rietkuil No. 86 either lies nearly flat or is gently folded in contrast to the fairly steep dips of the quartzite. This is indicated by an occasional exposed level ledge of lava passing underneath the quartz-porphyry along the right bank of the Schoon Spruit, the gentle westerly dip (5 degrees) of the lava on a small rise west of the railway on the western Townlands and the disposition of the dark Ventersdorp sedimentary beds to the north in the south-eastern corner of Rheebokfontein No. 37 and on Doornhoek No. 24. Further on Rietkuil No. 86 the Ventersdorp beds are certainly unconformable to the Lower Witwatersrand beds cropping out there. This is proved by the irregular boundary of the lava passing across various horizons of the older beds and by the presence of two small detached patches, one of lava, the other of volcanic breccia and lava, resting on the Witwatersrand quartzites and shales near the Afrikander mine. If, therefore, the lavas are conformable to the westerly inclined quartzites on the Klerksdorp commonage but unconformable to the quartzites and shales on Rietkuil No. 86, then the relation between the Ventersdorp and Witwatersrand formation is difficult to understand. It seems much more likely that the Ventersdorp beds are unconformable to the westerly and easterly inclined quartzites on the Klerksdorp Commonage as well as to the lower Witwatersrand beds on Rietkuil No. 86, and that the higher Witwatersrand beds are terminated in depth under the cover of volcanic rocks against earlier strata by one or more dislocations of pre-Ventersdorp age.

Practically in line between the Strathmore inlier and the one to the north of it on the Townlands is a small patch of the Black Reef Series which contains the conglomerate band known as " Niekerk's Reef ". The dip of the beds varies rapidly in angle and direction and the rocks generally are much broken in this little detached piece of the Black Reef Series which lies at a much lower level than the main mass of this formation forming the high ground 2,000 yards further to the east. The simplest explanation to account for the position of this patch of Black Reef Series and others like it on Nietgedacht No. 53 and on the northern boundary of the Townlands is that they were let down by the same faulting which affected the

Witwatersrand and Ventersdorp beds. (See figure 3.) If this explanation is correct then the faulting on the eastern Townlands and probably the Buffelsdoorn fault belong to a period of dislocation, which followed after the deposition of the Black Reef and Dolomite Series and is thus much later than the Pre-Ventersdorp step-faulting already described.

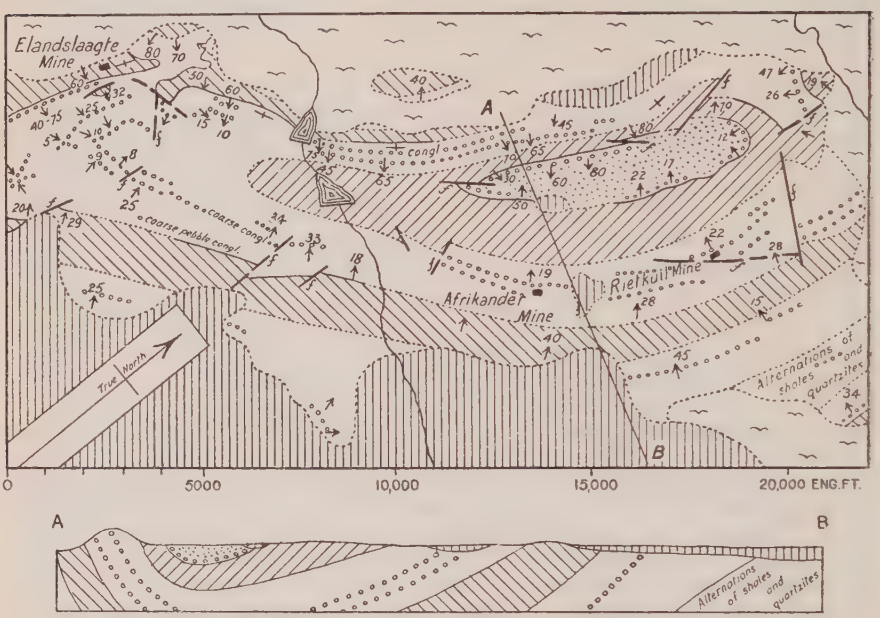
Structure of the Afrikander-Rietkuil neighbourhood.—The Witwatersrand beds in which the Afrikander and Rietkuil mines are located occupy a fairly large tract of hilly country stretching from Witpoort No. 95 in the north-east across Rietkuil No. 86 and adjoining farms to Rhenosterberghoek No. 88, the western boundary of which marks the furthest extension to the south-west the detailed survey has reached for the present. Beyond Rhenosterberghoek Witwatersrand beds still continue to crop out towards the south-west. In this area the Old Granite is also present and generally occupies the flat ground between the Witwatersrand beds and the escarpment of Ventersdorp beds to the west.

The large exposures of Rand beds in this part of the country which are completely separated on the surface of the ground from more extensive outcrops of this formation between Klerksdorp and Ventersdorp by a broad belt of Ventersdorp rocks some five miles across the narrowest width, present one of the most complicated pieces of structural geology in the whole of the Klerksdorp-Ventersdorp area. The Witwatersrand beds are so broken and disturbed that it is not easy to decipher the structure. The difficulty in this respect is much increased by large tracts of surface drift or alluvium which either render the tracing of the various horizons in detail a matter of the greatest trouble, or prevent it altogether.

From Witpoort No. 95 to the northern boundary of Rietkuil No. 86 the Witwatersrand rocks, which belong to the Hospital Hill Series except for the quartzites and shales of the Government Reef Series on the north-western part of Kafferskraal No. 36, are frequently interrupted by faults which cut the strike of the strata obliquely and on Witpoort are responsible for reduplications of the Contorted Bed and the beds adjoining it. They are normal faults, so far as their character can be determined, with a prevailing north-easterly–south-westerly trend. In contrast to the Rietkuil-Rhenosterberg neighbourhood to the south-west there is very little evidence of folding in this locality.

Emerging through a wide cover of alluvium between the northern boundary of Rietkuil and the Jagd Spruit on the same farm are a number of detached patches of Witwatersrand rocks. The disturbed character of the rocks generally and the position of one group of beds in relation to that of another show that apart from a certain amount of folding the rocks are faulted to a considerable degree. As much of the sediments is covered by alluvium the trend of most of the faults and their effect on the strata cannot be traced. The dislocations along some of the faults, however, are more evident. A fault running more or less parallel to the strike of the sediments is responsible for the elimination of a large thickness of the Hospital Hill Series to the north and south of Bonanza siding; while along or close to the northern boundary of Rietkuil No. 86 Government Reef beds are displaced by a transverse fault so that they come to rest in line with the strike of the Hospital Hill quart-

zite to the north of the farm. The partly inverted reef of the old West Bonanza mine too is cut off both to the north and south while in the direction of dip to the east the conglomerate curves up to the surface again.



PLAN AND SECTION OF THE RIETKUIL SYNCLINE.

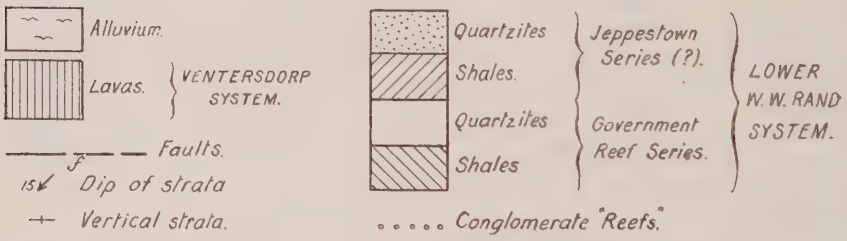


Fig. 4.

South of the Jagd Spruit beds belonging to the Government Reef Series rise to form the synclinal structure known as the " Rietkuil Syncline " (see section, figure 4), which extends to Elandslaagte No. 67, where the Witwatersrand rocks pass underneath the Ventersdorp beds. The axis of this syncline runs from north-east to south-west, is slightly concave to the north-west and curves downwards so that a longitudinal section of the structure will reveal a syncline in the same way as a transferse section would. The result is that the beds, where undisturbed by faulting, are always inclined towards the centre of the syncline. The extremities of this oval-shaped structure are much broken and dislocated by faulting, while minor oblique faults are present in the two limbs and also close to

the axis. The western limb of the Rietkuil Syncline probably lies against the same strike fault which eliminates much of the Hospital Hill Series to the north in the vicinity of Bonanza Siding, and in the low ground between the syncline and the Rhenosterberghoek hills the only outcrops are occasional occurrences of Ventersdorp rock, mostly cherty sediments or flagstones.

The Rhenosterberg, which rises from the lower ground occupied mostly by the Ventersdorp beds except to the north where the Old Granite forms the underlying rock, forms a prominent feature in the landscape south of the railway between Klerksdorp and Hartebeesfontein. It is built of the shales and quartzites that constitute the base of the Witwatersrand System and of these the ferruginous Water Tower shales or siliceous ironstones especially form prominent dark outcrops. The sudden changes in strike and the folding of these Witwatersrand beds once again afford ample proof of the disturbed character of the Witwatersrand System in this area. The crest of Rhenosterberg is occupied by a white resistant quartzite, and in following the contact of this rock with the underlying shales it was found that on Rhenosterberg the beds are thrown into a series of folds whose axes run north and south. On the adjoining portions of Rietkuil and Rhenosterberghoek the beds are probably less affected by folding than faulting which is responsible for the varying directions in strike.

Summary.

Witwatersrand beds associated with the Old Granite and rocks of the Ventersdorp System are exposed in the Klerksdorp-Ventersdorp area between the diverging limbs, formed by the Black Reef and Dolomite Series, of a broad denuded anticline of pre-Karroo age. The Old Granite as usual forms the basement upon which the Witwatersrand sediments rest, but between the Witwatersrand and Ventersdorp Systems a marked unconformity exists. The Witwatersrand beds are dislocated by faults and in some localities are also folded as a result of recurrent crustal movements during a considerable interval of time dating from pre-Ventersdorp to post-Transvaal times. Pressure movements seem to have alternated with tensional forces and in some localities the resultant structure presents considerable complexity.

A series of N.E.–S.W. trending step-faults, in age just prior to and probably correlated with the extensive Ventersdorp volcanic eruptions, are responsible for several reduplications of Lower Witwatersrand rocks over a broad belt of country between Klerksdorp and Ventersdorp. As a result strata higher than the topmost beds of the Government Reef Series or beds forming the base of the Jeppestown Series are not exposed. The only exception, apart from a doubtful quartzite and underlying shale on Palmietfontein No. 29, are the outcrops of quartzites on the Klerksdorp Commonage unconformable to one another and apparently both belonging to the Upper Witwatersrand division. In a broad belt of Witwatersrand rocks that trend south-eastwards to the vicinity of Klerksdorp the beds converge into narrower limits. This restriction is accompanied by overtilting of the lowermost Witwatersrand beds and the elimination of strata higher up in the succession. This structure probably is the result of pressure applied from the north-west, followed, possibly much later, by pressure from the south-east. In one case,

however, namely along the contact of the Government Reef and Hospital Hill Series, the disappearance of beds is due to the presence of a hinged fault. Faults, probably of post-Transvaal age and with downthrows to the east, terminate the uppermost Government Reef quartzite (Buffelsdoorn Reef quartzite) and overlying shale against the Ventersdorp rocks on Buffelsdoorn No. 58 and Palmietfontein No. 29, and are responsible for the reduplication of Witwatersrand quartzites on the Klerksdorp Commonage and possibly also for the preservation of the Black Reef Series in narrow downfaulted blocks west of its main line of outcrops. In the Afrikander-Rietkuil neighbourhood the most important and characteristic feature is the Rietkuil Syncline formed by beds of the Government Reef Series. To the west and to the north-east of this structure the strata, mostly beds belonging to the Hospital Hill Series, are folded on occasion and frequently interrupted by faults.

GENERAL ACCOUNT AND CORRELATION OF THE WITWATERSRAND SYSTEM.

The ancient group of shales, siliceous ironstones, quartzites and conglomerates which constitute the Witwatersrand System has yielded no fossils, and thus, in the absence of any palaeontological evidence, the classification and correlation of the beds are dependent upon a detailed study of the lithological characters and the sequence of its various constituent members. The Witwatersrand System, as represented on the Central Rand, the type locality for this formation, is nearly 25,000 feet thick, and falls naturally into two major portions in the lower of which argillaceous or fine-grained sediments are predominant, while the upper consists of a continuous succession of quartzites, grits and conglomerates interrupted only by the persistent group of Kimberley shales and, now and again, in some localities, by a minor lens or two of shaly rock. The lower division is further subdivided into the Hospital Hill, the Government Reef and the Jeppestown Series; the upper division into the Main-Bird and Kimberley-Elsburg Series. This classification which was established by Dr. E. T. Mellor on the Rand, provided the basis for the investigation of the Witwatersrand System in the Klerksdorp-Ventersdorp area.

Characteristic of the Witwatersrand System is the presence in it of some remarkably persistent rock units that retain their distinctive character over great distances, and, as several of these well-known key-horizons, or "markers", of the Rand are also present in the Klerksdorp-Ventersdorp area the correlation and classification of the strata exposed there was considerably facilitated. The key-horizons common to both areas are, in ascending order, the Orange Grove quartzites, Water Tower Slates, Speckled Bed, Contorted Bed, Hospital Hill quartzites and the Tillite. All except the last, which belongs to the Government Reef Series, are in the Hospital Hill Series. A complete sequence of the upper division of the Witwatersrand System and the Jeppestown Series underlying it is not exposed in the Klerksdorp-Ventersdorp area so that, in the absence of any evidence from boreholes, it is impossible to say whether the Kimberley Shales and the Bird Reef Amygdaloid or Marker, the two most important markers in the Upper Witwatersrand, extend into that area. The thick mass of quartzites, belonging presumably to the Upper Wit-

watersrand division, on the Klerksdorp Commonage is unrelieved by a single thick band of typical shales nor do they contain an interbedded volcanic rock corresponding in character to the Bird Reef amygdaloid.

In a great mass of sediments such as that of the Witwatersrand System modifications in the extent, thickness, materials and texture of the beds are bound to occur from place to place. It is because of such changes that in the Klerksdorp-Ventersdorp area difficulty was encountered in trying to establish definitely the exact horizons that limit the Hospital Hill and Government Reef Series in the Rand. The selection of a division line was made with the object in view not to exclude features by which the stratigraphic division affected is characterized.

In the general description of the Witwatersrand rocks which follows attention is drawn to the fact that most of the quartzites show current-bedding, while ripple-marks are also frequent on the bedding planes of both quartzitic and argillaceous rocks.

The Hospital Hill Series.

A glance at columnar sections C, F, G and M in Fig. 5 (Fig. 5, folder at end of volume) will show that there are two large quartzite groups separated by a belt of shales and thicker than any similarly placed quartzites in the Rand. It will also be noticed that the lower group is made to correspond to the highest quartzite band in the Hospital Hill Series. There may be some doubt whether it is correct to include this quartzite in the Hospital Hill Series instead of placing it in the Government Reef Series, for much is to be said for a line drawn along the top of the first thin quartzite, No. 18, encountered in the succession below the thick quartzite to represent the base of the latter series. If this is done the thickness of the Hospital Hill Series will be more in conformity with that on the Rand. Moreover, in contrast to the top of the thick quartzite, which is very seldom exposed, the thin quartzite always rises in distinct outcrops. This fact, coupled with its association with a black fairly ferruginous shale just above it, affords an easily recognized and therefore convenient horizon for correlative purposes.

On the other hand, the general appearance and composition of this broad quartzite (or at least its lower half, because the upper part is less resistant and occupies flat ground) are more like those of the Hospital Hill Quartzites than those of the Government Reef Series which are mostly dull-weathering and less purely siliceous rocks. The tendency to develop the well-known "sago" structure and the occasional presence of the characteristic green colour were noticed, though quartzites of the Government Reef Series sometimes also exhibit similar but generally less pronounced characters. Further, by including this thick quartzite in the Hospital Hill Series arenaceous rocks form about 39 per cent. of the total thickness in an average section, which is almost the same as that in the Rand and Heidelberg, viz., 38 per cent. and 36 per cent. respectively. Without the thick quartzite the proportion of quartzites to argillaceous rocks is only about 20 per cent. With regard to the great thickness shown by the quartzite it is a point of interest that the topmost Hospital Hill quartzite in the Far West Rand is much thicker than it is close to Johannesburg. It may thus be possible that this progressive increase towards the west continues as far as the Klerksdorp-Venterdorp area.

Basal Volcanic Rocks.—Between the lowest band of Orange Grove quartzites and the Old Granite a group of volcanic rock is almost always present. This consists of lavas and bedded light-grey ashy-looking rocks. The dip of the latter correspondens to that of the overlying Orange Grove quartzite. Some of the lavas are curious cherty amygdaloidal rocks and appear to be acid igneous rocks partly or wholly silicified; others are dark vesicular rocks somewhat more basic in composition. Intercalated with the amygdaloidal lavas is a dense dark porphyry. The phenocrysts are mostly little plagioclases and sometimes specks or small crystals of quartz are also present. These volcanic rocks appear to be in the form of lenticular bodies or flows and it is not often that all three are represented in one exposure. The group is as a whole subject to variations in thickness from a few feet to well over 500 feet. The basal lavas and those of the Ventersdorp System adjoin in various localities and it was often difficult to decide where the boundary between the two formations had to be drawn, because of some similarity between certain lavas of the basal group to those of the Ventersdorp and because of indifferent exposures of the contact.

The Orange Grove Quartzites.—These are the lowermost quartzites of the Witwatersrand System. They are hard fine-grained rocks, bluish-, yellowish- or brownish-white on the weathered surface, and, being very resistant to weathering, often rise into bold ridges which overlook flat country occupied by the Old Granite. In the Klerksdorp-Ventersdorp area these quartzites are not so strongly developed and there are generally two or three bands (Numbers 1, 3 and 5 in figure 5) compared with four or more on the Rand. In the Rietkuil-Witpoort neighbourhood apparently only two bands are represented of which the lower also fades away in places. The quartzites are essentially fine-grained and have no conglomerates. South of Hartebeestfontein a group of arenaceous rocks known as the Dominion Reef Series, rests directly upon the Old Granite and has well-marked conglomerates at or close to the base. Whether this formation forms part of the basal members of the Witwatersrand System or not I am unable to say at present as the detailed mapping has not extended to that part of the country.

The Water Tower Slates.—The Orange Grove quartzites are associated with a broad belt of reddish or brownish black-weathering shales and some dark fine-grained sandstones or quartzites. These rocks are often very ferruginous and in places carry magnetite. In this shale group, which may be correlated with the Water Tower Slates of the Rand, occasional thin bands of ordinary light-coloured quartzite appear. They are mostly inconstant except for one band, sometimes split in two, which is in a position relative to the adjoining beds similar to that of the Ripple-marked Quartzite in the Rand, but whether it is actually the extension of that rock unit is uncertain.

The Contorted Bed.—Prominent outcrops are formed by the thick group of dark rather hard shales and siliceous ironstones in which is included the Contorted Bed. Conspicuously banded as usual due to alternations of jaspery, cherty and magnetite-bearing laminae, the Contorted Bed frequently reveals the characteristic corrugations from which its name is derived. The Contorted Bed forms the highest part

of the ridge on the south-eastern part of Syferfontein No. 137 and the adjoining part of Leeuwfontein No. 21; prominent outcrops extend from Blesbokfontein No. 15 to Bulskop No. 97 and Lustfontein No. 126, and it is also strongly developed on Kromdraai No. 75, Rooipoort No. 29 and Witpoort No. 95.

The Speckled Bed.—A felspathic quartzite 4 to 9 feet thick which in places is quite coarse and even gritty is generally in place about 170 to 200 feet below the Contorted Bed and may therefore safely be correlated with the similarly placed Speckled Bed in the Rand.

The Hospital Hill Quartzites.—The white-weathering quartzites numbered 12, 14, 16, 18 and 21 in the columnar sections (see Fig. 5) are the equivalents of the Hospital Hill quartzites in the Klerksdorp-Ventersdorp area. Excluding No. 16 which is only a few feet thick, and the upper part of No. 21 which is mostly covered, the quartzites are hard resistant rocks which give rise to prominent ridges or conspicuous outcrops. No. 18 is a thin quartzite as well, though thicker than No. 16, but it is persistent throughout the area mapped and usually affords good outcrops. The two lowermost bands, separated by a group of quartzitic shales and thin-bedded or flaggy grey quartzites, are mainly fine-grained quartzites in contrast to the remaining three bands which are of coarser types, especially the large quartzite mass, No. 21, in which there are many grit bands together with an occasional small pebble conglomerate. In these coarser quartzites the grains are generally well-rounded and in places sago-structure is also developed.

Immediately above quartzites Nos. 14 and 18 the shales are of a black-weathering ferruginous type while the shales between quartzites 16 and 18 are also ferruginous in places. The flaggy argillaceous beds between two fine-grained quartzites followed higher up by the association of white medium- to coarse-grained quartzites with black ferruginous shales are constant features very characteristic of the upper part of the Hospital Hill Series throughout the Klerksdorp-Ventersdorp area. This sequence, partly or wholly exposed, proved an excellent guide to the correlation of the strata and a valuable aid in deciphering the structure of the Witwatersrand beds there.

The Government Reef Series.

The top of the quartzite which includes the Buffelsdoorn, Afrikander and other conglomerate "reefs" is made to correspond with the upper limit of the Government Reef Series in the country around Klerksdorp. This arrangement, however, can only be tentative because definite evidence which could indicate the particular horizon which limits this series in the Rand is lacking in the Klerksdorp-Ventersdorp area. Above the Buffelsdoorn or Afrikander Reef quartzite only a shale and quartzite were found. There are no exposures of strata following immediately upon these beds. Further, two important markers in the Government Reef Series, viz., the magnetic West Rand Shales and the Government Reef, have not been recognized with certainty there. The belt of shales which include the heavy ferruginous and laminated West Rand or Coronation Shales follows above the tillite in the Heidelberg

area and also in the Rand. The tillite of the Klerksdorp neighbourhood is succeeded by some 200 feet of shales. If these shales, because of their position above the tillite, are identical with the West Rand Shale group then they have lost that highly magnetic character which is so typical of the latter. There is also nothing like the West Rand Shales above the lower tillite in the Klerksdorp area. Argillaceous rocks which in places are somewhat ferruginous and occasionally show small octahedra or specks of magnetite underlie quartzite No. 32, which includes the Buffelsdoorn, Afrikander and other conglomerate "reefs". These ferruginous rocks are the closest to the tillite but they have not that marked magnetic and banded character of the typical West Rand Shales; besides they are separated from the tillite by at least 1,100 feet of quartzites and shales.

The only conglomerate which could possibly represent the Government Reef in the Klerksdorp neighbourhood is one that is usually present in the lowest part of quartzite No. 32. This conglomerate either rests directly on shale or very close to the shale contact, and it varies from less than a foot thick to about eight or more feet in places. Usually it is a large pebble conglomerate in which individuals up to about eight inches long are found. The pebbles, mostly of quartz and quartzite, are well-rounded but not well sorted, as large and small pebbles are indiscriminately mixed together. On the whole this conglomerate is both coarser and thicker than the Government Reef in the Rand. Should this conglomerate prove to be the equivalent of the Government Reef then the possibility of the Coronation Reef also being represented there is of interest. Above the shales resting on the upper tillite band is about 1,000 feet of easily weathered medium- to coarse-grained quartzites and sandstones (No. 30) in which inconstant shale bands may appear. Along the base of this arenaceous group is a narrow band of coarse grit which in places develops into a small pebble conglomerate, and it is this rock unit which is rather suggestive of the Coronation Reef.

With the upper limit of the Government Reef Series being drawn along the top of quartzite No. 32 the total average thickness of the Hospital Hill and Government Reef Series exposed in the country between Ventersdorp and Klerksdorp show an increase, probably in the neighbourhood of 1,500 feet, if not more, on the figure for the combined thickness of these two major sub-divisions on the Central Rand. The increase in thickness, as shown in Fig. 5, is mainly expressed in the strong development of quartzites at the top and bottom of the Hospital Hill and Government Reef Series respectively. On the West Rand an increase in the thickness of the Hospital Hill and Government Reef Series is experienced, and, as a matter of fact, the total thickness there may be as great as, if not greater than, in the Klerksdorp occurrence. The general tendency, therefore, appears to be for the Lower Witwatersrand, or at least its two lowest series, to increase in thickness from the Central Rand towards Klerksdorp. Judging by the number, the thickness and in some cases the coarse texture of the pebble bands in certain quartzites, especially on Elandsheuvel No. 54 and in the Rietkuil Syncline, it appears that the increase in thickness is accompanied by an increasing coarseness of texture of the rocks generally. This is further confirmed by a distinct increase in the proportion of quartzite to argillaceous rocks in the Klerksdorp-Ventersdorp area. A comparison shows that in the Central Rand quartzites to argillaceous rocks are in the ratio of 38 to 62 for

the Hospital Hill Series and 69 to 31 for the Government Reef Series. In the Klerksdorp-Ventersdorp area the Figs. are 39 to 61 and 79 to 21 respectively.

The lowest member of the Government Reef Series in the country between Ventersdorp and Klerksdorp is a shale group. The shales are soft, bluish-black or brownish on the surface, easily weathered and consequently seldom seen in good outcrops. The shales are sandy in parts and possibly also include thin bands or lenses of fine-grained rusty brown sandstones. The best exposures of this group are on Rheebokfontein No. 37, Buffelsdoorn No. 58, Syferfontein No. 21 and in two old trenches north-east of the road in the south-eastern corner of Rooipoort No. 29. The quartzites immediately above and below the shale group are soft and rarely crop out, and as a result an exposure revealing the full width of the shales was not found. The true thickness of the shales thus could not be established, but it is probably in the neighbourhood of about 200 feet.

The shales are succeeded by a remarkably thick group of quartzites, which in some localities appear to be fully 3,000 feet or more thick. A quartzite group as thick as this does not exist in the Lower Witwatersrand division of the Rand, Heidelberg or Vredefort areas. It is possible of course that there may be discrepancies between the thickness given for these beds in some of the columnar sections (Fig. 5) and their actual thickness because measurements were made across zones in which rocks are not exposed, and because uniformity of dips and absence of faulting by which the strata may locally have been thickened were assumed. Yet taking these factors into consideration the dimensions are still such as to be exceptional for any group of arenaceous rocks in the Lower Witwatersrand System. The lower part of the group is composed mainly of easily weathered rocks which, except for occasional small exposures, are usually covered by sandy surface drift or alluvium. These rocks appear to be mainly soft micaceous sandstones, probably shaly in parts, which include grit bands. In places scattered pebbles and thin pebble washes were seen, while well-marked but inconstant conglomerates were opened up on the central part of Syferfontein No. 21. The conglomerates are mostly made up of small pebbles less than an inch across and more or less of the same size, but now and again there are individuals as much as 4 inches in length. The pebbles are mostly of glassy, milky and dark grey quartz; there are others of chert (sometimes banded) quartzite, a nondescript dense light greenish-grey rock and red shale. The upper part of the quartzite group, on the other hand, is formed of massive resistant medium- to coarse-grained quartzite and gives rise to the prominent ridge which extends from Syferfontein No. 21 across Buffelsdoorn No. 58 to the southern boundary of Rheebokfontein No. 37, while the kopje on the north-western part of Kafferskraal No. 36 is also formed by these quartzites. Gritty bands are numerous and in places pass into thin lenses of small pebble conglomerates. A conglomerate band of somewhat greater persistence, known in the past as the " Red Reef ", is located near the top of the quartzites. The pebbles are mainly of quartz together with some of quartzite and plain and banded chert. Judging by the numerous old prospecting trenches and pits sunk on it, the conglomerate is auriferous in a minor degree. The conglomerate is generally to be found close to the foot of the eastern slopes of the prominent ridge that stretches across Buffelsdoorn No. 58 and Rheebokfontein No. 37; it is also present on the broad rise to the east of the pan on Eleazar No. 18.

Between the large quartzite group and the lower tillite band is a succession of shales and standstones or quartzites which vary rather rapidly in thickness and texture from place to place. Much of these shales is sandy and the sandstones thin-bedded and shaly. Lenses or bands of the usual pale-coloured quartzites do occur in some localities and tend to be coarse gritty rocks with occasional scattered pebbles. A similar succession of rocks occurs between the two tillite bands though bands of pale-coloured quartzites are more frequent. These quartzites are medium- to coarse-grained and gritty rocks including in places, as on Welgegund No. 38 and Palmietfontein No. 29, scattered pebbles or closely-packed conglomerates in which pebbles up to four inches long are not unusual. One of these quartzites is usually in place just below the upper tillite. It is a thin coarse-grained or gritty quartzite, is generally pitted on the weathered surface, and often contains inconstant conglomerates two or more bands of which may combine to form a single pebble bed up to four or five feet thick. These pebble-bands, together with the tillite above, have often received the attention of the prospector as witnessed by the many old trenches and pits in which they are exposed.

The Tillite.—The presence of a tillite in the Government Reef Series was first recognized by Rogers in the Heidelberg District.* Since then its presence has been proved in the Rand and subsequently Rogers also discovered this rock in the Klerksdorp area a little to the west of the old Buffelsdoorn mine.

On Buffelsdoorn there are two distinct bands of tillite separated, as already mentioned, by a succession of shales and quartzites or sandstones probably some 600 and more feet thick. A thin lens of tillite was also noticed higher up in the succession lying just below No. 30 quartzite on Palmietfontein No. 29 near the northern boundary of the farm. The tillites vary in thickness. The greatest thickness attained by either of the tillite bands is in the neighbourhood of a hundred feet on Buffelsdoorn No. 58, but generally they are much thinner. The upper band appears to be constant, but the lower gradually becomes thinner in a south-westerly direction until close to the Welgegund-Buffelsdoorn boundary it passes into a narrow dark gritty rock in which pebbles are rare and in which it will be difficult if not impossible to recognize a tillite. From here further to the south-west it occasionally reappears in the form of thin inconstant bands at or close to the same horizon. In the Rietkuil No. 86 neighbourhood a rock bearing a close resemblance to the tillite was found exposed in some prospecting trenches in the north-western part of Kafferskraal No. 36 and the eastern part of Rietkuil No. 86. It is probably a tillite, but whether it represents one of the two bands exposed on Buffelsdoorn or another development close to either of these horizons is difficult to say because of poor outcrops and the complicated structure of this part of the country.

The two tillite bands on Buffelsdoorn were at first thought to be a repetition of a single band by faulting, but although the rocks immediately associated with each band are similar actual sequence in each case is not identical. The upper tillite has a thick belt of shales above it and usually rests on a small gritty or pebbly quartzite; the

* Rogers, A. W. "The Geology of the Country Around Heidelberg", Geological Survey, Union of South Africa, p. 20, Pretoria, 1922.

lower has a fairly thick quartzite immediately above or fairly close to its top, while it is underlain by thin inconstant bands of shale, quartzite or sandstone.

On a fresh fractured surface the tillite is dark grey in colour. The dense matrix contains many coarse and fine grains, often angular, of glassy quartz together with some small fragments of the rocks of which the pebbles are made. Pebbles and boulders are scattered at random through the rock and lie in various positions. They are mostly of quartz and quartzite; others are of grit, chert sometimes banded, and a dense cherty lava. Some of the quartz pebbles are of black lustrous quartz, others have white or greyish centres with dark peripheries. The pebbles and boulders range in size from less than an inch up to a foot and more in length; they are rounded, sub-rounded, or flattened on one or more sides. Striated pebbles were found, but are comparatively rare.

The tillite, as already mentioned on page 22, is overlain by a shale which in turn is succeeded by a thick group of quartzites (No. 30) followed by another belt of shales (No. 31). Pebble bands are seldom seen in quartzite No. 30 between Buffelsdoorn No. 58 and Elandsheuvel No. 54, but in the Rietkuil No. 86 area they are more frequent and locally even develop into well marked large pebble conglomerate lenses several feet thick.

The next quartzite group (No. 32 in the columnar sections) up in the succession is economically one of the most important members of the Witwatersrand succession in the Klerksdorp area, for in it are included the auriferous conglomerates which were exploited in the past by the old Buffelsdoorn, Pope and Elandslaagte mines, and which are still being worked by the Afrikander and the recently restarted Rietkuil mines. The auriferous conglomerates or " reefs " of the various properties do not necessarily occur at or close to the same horizon. The reefs of the Afrikander and Rietkuil properties for example, may be at or very close to a common horizon, but the old Elandslaagte mine, on the other hand, worked a large pebble conglomerate lower down in the same quartzite. Again the Buffelsdoorn, or " White Reef " as it is sometimes also called, is at a higher horizon than the reef of the old Pope's mine.

The quartzites forming this group are largely medium- to coarse-grained and gritty rocks. The lower part of the group is composed of dull-weathering rather soft rocks, but the rest are of a lighter tint at the surface, more resistant to weathering and frequently give rise to conspicuous outcrops which mark the upper part of the group. In the lower part there is a band of coarse quartzite, deep reddish or purplish red at the outcrop, which is generally associated with or includes large pebble conglomerates, while many scattered pebbles may also be present, as on Elandslaagte No. 67. Flakes of white mica are of common occurrence, especially in the darker quartzites. Scattered pebbles, thin pebble washes and conglomerates are frequent. Individual conglomerates rarely persist for more than a mile or so, and in some cases extend over a length of only a few hundred feet. The pebbles, which are mainly of quartz, quartzite and chert often striped, are frequently large and individuals as much as six inches long are not uncommon. There is a gradual increase in the number and size of the pebble beds attended by an increasing coarseness of texture as the quartzite is followed from Buffelsdoorn No. 58 to

Elandsheuvel No. 54. In the Rietkuil Syncline beyond the intervening belt of Ventersdorp beds these quartzites are also characterized by the many and well marked conglomerates, individual bands of which may be very coarse pebbled. The coarsest conglomerates are located in the lower part of the group, and in the Rietkuil Syncline a large pebble conglomerate, locally known as the " Big Pebble Reef ", varying in thickness up to about 24 feet, is present 50 to 70 feet below the Afrikander and Rietkuil reef zone. On Buffelsdoorn No. 58 a similar but thinner large pebble conglomerate is in place about 75 feet below the Buffelsdoorn reef and possibly is at or close to the same horizon as the Rietkuil " Big Pebble Reef ".

The Buffelsdoorn Reef.—In the shafts and pits of the old Buffelsdoorn mine a conglomerate band is exposed which varies in thickness from a mere parting up to $2\frac{1}{2}$ feet. There may be only a single line of scattered pebbles, often large, which in places become more abundant and closely packed to form conglomerate lenses. In one locality where the conglomerate is about two feet thick, the pebbles are closely packed and large, some individuals being about nine inches long. The pebbles are not well sorted, large pebbles occurring along with small ones and not being necessarily confined to the base of the conglomerate. Above the conglomerate there is often a coarse quartzite or grit band more or less a foot thick followed by a line of scattered pebbles. For the next four or five feet the quartzite is coarse-grained with local grit bands and is followed upwards by quartzite, mostly medium- to coarse-grained, white or light-coloured at the outcrop, which forms the upper part of the whole group. Occasionally the conglomerate passes upwards through a zone of scattered pebbles into quartzite. In places there are specks or stringers or carbon, the presence of which was found to coincide with some of the richest, at times phenomenal, values obtained in the old mine. According to Hatch and Chalmers, the gold contents are not confined to the pebble band, being chiefly present in streaks in the overlying coarse-grained quartzite, so that the pay body was about 3 to 4 feet in width.*

The Reef of the old Pope's Mine.—The reef exploited in the old Pope's mine on Elandsheuvel No. 54, as far as could be ascertained from the old and often fallen-in workings, is a small pebble conglomerate of variable thickness; the average thickness is probably about one foot, but in places it is divided in two thin bands by a quartzite parting. The reef is not persistent and to the north-east passes into a grit. The average size of the pebbles is about half an inch across, but there are individuals which may reach up to 3 inches in length, which show a tendency to collect in the lower part of the conglomerate. This reef is located in the belt of dark reddish-weathering quartzite mentioned above.

The Afrikander-Rietkuil Reef Zone.—The reefs worked in the Afrikander mine and the adjoining Rietkuil mine are most probably located within the same zone of conglomerates, although, on account of some local faulting and the presence of a thin covering of Ventersdorp beds in the form of a small outlier between the two mines, a

* Hatch, F. H., and Chalmers, J. A. " The Gold Mines of the Rand ", London, 1895, p. 19.

direct connection between the ore-bodies could not definitely be established by following the strata on the surface. On both properties the auriferous conglomerate zone which occurs at about the same height (50-70 feet) above a thick belt of a very coarse pebble conglomerate, the " Big Pebble Reef ", comprises a number of pebble beds of variable thickness and mostly inconstant. It so happens that on both properties interest is centred in three of these conglomerate bands, or thin conglomerate zones, spoken of as the Lower, Middle and Upper Reefs. In each of these reefs or pebble zones there may be one or more conglomerate layers, none of which seem to be essentially continuous, but occur rather in the form of many discontinuous lenses at about the same horizon.

In the Afrikander mine the Upper Reef is from 14 to 20 feet above the Middle Reef and the Middle and Lower Reefs are about 40 feet apart. The quartzites separating the reefs contain some thin pyritic stringers, scattered pebbles and thin inconstant conglomerate bands, several of which may carry poor values. Such slightly auriferous bodies may also be found in the quartzite above and below the Afrikander-Rietkuil reef zone. The reefs are usually split into two or more bands of variable thickness by quartzite partings. The latter are lenticular or are also subject to changes in thickness from place to place. The average size of the pebbles constituting the conglomerate reefs is much smaller than that of the conglomerates lower down in the quartzite mass.

In both the Upper and Middle Reefs, which have no well-defined hanging- and footwall partings, the average thickness of the pay bands is about 8 inches and in the stope widths of 32 to 36 inches one or more six- to eight-inch reef bands carrying low values up to about 6 dwts. are included. The average value of the pay band, in the case of both reefs, ranges from about 15 to 20 dwts., but these figures are only very approximate. Some carbon is usually present on the footwall contact of both these reefs. Favourable portions of the Lower Reef pay zone carry two or three payable reef bands of about nine inches. The two upper bands carry moderate values in these portions, but are not persistent over the whole area. The bottom band, regarded as the chief pay band, carries about 20 to 30 dwts. Here again carbon is usually found on the footwall contact and is associated with exceptionally high values. The area covered by the pay zone of the Lower Reef is not as extensive as that of the Upper and Middle Reefs, but its three payable bands allow of an increased stope width of about 55 to 65 inches.*

At the time of my visit the Rietkuil mine was still being dewatered, but it seems that the reefs developed in the past were the the Lower and Upper Reefs as the values found in the Middle Reef were low. The Upper Reef from about 1½ to 3½ feet thick is parted in places by thin quartzite lenses, and, compared with some of the other conglomerates in this belt of quartzites, is a small pebble conglomerate in which there are occasional large scattered pebbles. The average sized pebble is about an inch or less across. The Lower Reef is composed of thin washes or bands of pebbles separated by coarse, often gritty, quartzite over a thickness of about 4 feet in places. The pebbles in these bands are usually not closely packed, with the exception perhaps of the lowermost band. On the whole the pebbles are

* For the information contained in this paragraph the writer is indebted to J. Johnson, Esq., Manager of the Afrikander Mine, Afrikander Lease, Limited.

also small although individuals up to 4 inches long are more frequent than in the Upper Reef. The values are stated to be mostly confined to the lowermost part of the reef. The Middle Reef is similar to the Upper and has an average thickness of about two feet.

The Reef of the old Elandslaagte Mine.—The old Elandslaagte mine developed a coarse pebble conglomerate which most likely is identical with the Big Pebble Reef below the Afrikander-Rietkuil reef zone, and placed at about the same distance above the shales lower down in the succession. Only a portion of the thick conglomerate mass was worked, for although some of the inclined cavernous excavations or drives reach fully ten feet in height, the remainder of the conglomerate is still left in the hanging and foodwall. Quartzite partings varying rather rapidly in thickness divide the conglomerate into two or more bands. In places the pebbles are closely packed but further along many become more dispersed in an increasing volume of coarse quartzite or gritty matrix.

The Jeppestown Series.

Above No. 32 quartzite is a band of shales followed by a quartzite of unknown thickness numbered respectively 33 and 34 in the columnar sections. As already indicated, these beds possibly represent a part of the Jeppestown Series. On Buffelsdoorn No. 58 and Welgegund No. 28 only a remnant of the shale group appears along the fault terminating the Witwatersrand beds against the Ventersdorp rocks, but on Palmietfontein No. 29 and Elandsheuvel No. 54 where the strike of the beds swings away from the fault to a more westerly direction the shales are well exposed. Their thickness there is probably in the neighbourhood of about 500 feet. These shales also appear in the Rietkuil Syncline overlying the quartzite which carries the Rietkuil and Afrikander reefs (see Fig. 4). The average thickness there is about 300 feet. The group is composed of ordinary shales together with some bands that are more sandy in character. On Palmietfontein No. 29 flaggy rocks or thin-bedded argillaceous sandstones were noticed in the lower part of the group. In places the shales are slightly ferruginous, but no magnetite crystals were seen. At the outcrops these rocks are dark reddish, brownish and greenish-grey in colour.

Quartzite No. 34 is partially exposed in the north-eastern corner of Elandsheuvel No. 54, and it occupies also the central part of the Rietkuil Syncline. It is a medium to coarse-grained rock in which white mica is frequently seen, weathers easily and thus forms no prominent outcrops. At the outcrop its colour is mostly a dull reddish brown. On Elandsheuvel No. 54 it contains a few scattered pebbles which in places may develop into a thin conglomerate lens. In the Rietkuil Syncline pebble beds are more abundant and well-marked in the quartzite, especially towards the base. These conglomerates, locally known as the " Inner Basin Reefs " vary in thickness from place to place and are apparently lenticular in shape. The most constant pebble bed is probably one which is near the base of the quartzite which received attention in the past and which at the time of my visit was again being opened up on the Afrikander property in a series of inclined drives. This conglomerate may reach up to five feet in

thickness including quartzite partings. The pebbles, though well-rounded, are not particularly well sorted, for both large and small pebbles are irregularly associated. Individual pebbles may attain a length of four inches.

In the middle of Palmietfontein No. 29 beside a dam across the spruit there is an outcrop of a quartzite, dipping to the south-east, with a shale underlying it. The quartzite contains a thin band of conglomerate on which an inclined shaft was sunk in former years by the Buffelsdoorn Consolidated Gold Mining Company. Rocks west of the shales are concealed by a covering of alluvium which also extends as a narrow strip between this shale and the quartzite above it, and further shales and quartzites to the north. Ventersdorp rocks limit their eastern and southern extensions on the surface of the ground. The structure of this locality is very complicated as the result of faulting, and the unravelling of it is rendered most difficult because of the flatness of the country and the lack of outcrops. At first glance one is tempted to regard the quartzite as an extension, due to faulting, of the Buffelsdoorn reef quartzite which crops out a short distance to the north. Closer investigation, however, reveals that the shale underlying the quartzite is not the same as that which is below the Buffelsdoorn Reef quartzite; nowhere does it possess that ferruginous character which distinguishes the upper part of the latter shale and on the whole appears to be a different shale altogether. On the other hand it bears a much closer resemblance to the shales overlying the Buffelsdoorn Reef quartzite exposed on the western part of Palmietfontein No. 29. It seems very likely that this shale and quartzite do not belong to the Government Reef Series but occur somewhere higher up in the sequence of Witwatersrand beds. They may possibly represent a faulted portion of the shale and quartzite (Nos. 33 and 34 in the columnar section) exposed above the Buffelsdoorn Reef or Africander Reef quartzite on Elandsheuvel No. 54 and in the Rietkuil Syncline.

The Upper Division of the Witwatersrand System.

The South-easterly Dipping Quartzites.—Reference has already been made to two quartzite groups, unconformable to one another, cropping out on the Klerksdorp Townlands and the adjoining part of Elandsheuvel No. 54. The quartzites constituting the lower group (No. 35) are massive medium- to coarse-grained rock with a yellowish or brownish colour at the outcrop. They include several conglomerate bands such as the Ada May and Commonage reefs, while grit bands that occasionally develop into inconstant small pebble conglomerates are often present. In places there are also scattered pebbles in the quartzite, especially in the vicinity of conglomerate bands such as the Ada May reefs for example. Further, flakes or specks of white mica are frequently noticed in these rocks. A belt of soft reddish or purplish weathering quartzite or sandstone, mostly covered by alluvium or surface drift, extends from near the right bank of a small spruit where it crosses the Elandsheuvel-Palmietfontein boundary, past the western slopes of the Ada May kopje and of the prominent hill further to the south to disappear eventually in the direction of the elevator underneath the unconformably overlying quartzites. In places there is a tendency for the sandstone to pass into a soft sandy rather micaceous shale as, for example, on the eastern slope of an

isolated bush-covered hillock in the south-eastern corner of Elandsheuvel No. 54 not far from the Commonage boundary. The lower quartzite group, therefore, is divided by this belt of soft reddish or dark sandstone into two portions, the upper one of which carries the Ada May and Commonage Reefs. As neither the top nor the base of this quartzite has so far been found its true thickness could not be determined; nor are the correct positions of the various conglomerates, relative to its base or top, known.

An Interbedded Lava Sheet.—An unusual occurrence on the eastern part of Elandsheuvel No. 54 is that of an amygdaloidal igneous rock of rather acid composition and probably not more than about 200 to 300 feet thick, which apparently belongs to the lower portion of the quartzite group. At this spot the easterly dipping quartzite (No. 35) is unconformably overlain by the westerly inclined quartzite (No. 36) which has a basal conglomerate. The strike of the amygdaloid, which in places lies against the basal conglomerate, corresponds to that of the lower quartzite. Southwards it tapers out, apparently because the upper quartzite passes unconformably across it, and to the north along with the two quartzites it disappears in a patch of deep soil covering a fault. Between its northern and southern extremities the amygdaloid leaves the basal conglomerate to reveal along its western margin the presence of a portion of quartzite No. 35 standing vertical or dipping steeply to the east. The true relationship of this amygdaloidal rock to the quartzite is somewhat obscure because of minor dislocations in places along its margins and because at first it is not fully realized that the amygdaloid is associated there with two different quartzites one unconformable to the other. The dense aphanitic matrix and amygdaloidal character of the igneous rock, the presence of a thin tuff or fine-grained voclanic breccia lens in a laminated part of the rock which reveals a steep easterly or vertical dip in contrast to the 20 to 30 degrees westerly dip of No. 36 quartzite, indicate an inter-bedded volcanic rock, contemporaneous with the lower (No. 35) quartzite.

The Ada May Reefs.—Cropping out on an isolated kopje (Ada May kopje) to the north-east of Klerksdorp and about 1,200 yards north of the railway are two or more conglomerates bands known as the Ada May Reefs. If these reefs are followed from there in a north-easterly direction it is found that before the northern boundary of the Commonage is reached they bend round to strike in a south-easterly direction and eventually disappear, probably terminated by a fault in the low ground along the spruit. After being displaced about 300 yards to the south-east along a dip fault just south of the kopje the reefs trend in a south-westerly direction, cross the railway to ascend and occupy the crest of the prominent hill east of the railway station. Down the southern slope of this hill the Ada May reefs enter into highly disturbed ground in the vicinity of an oblique fault, where in places they are overtilted or crushed closer together, dislocated and finally terminated. At the Ada May kopje the Ada May reefs comprise four rather thin conglomerate bands in about a hundred feet of quartzite. Some of these bands, however, are not persistent, for generally there are only two pebble beds separated by coarse-quartzite carrying scattered pebbles and subject to rather rapid variations in thickness. Quartzite partings of variable thickness are frequent in

the conglomerates. The well-rounded constituent pebbles of the conglomerate are rather coarse, averaging well over an inch in length, while individuals up to six inches long were occasionally seen. The pebbles are mostly quartz, glassy black, greyish and white varieties, together with some of quartzite.

The Commonage Reef.—The next well-marked conglomerate or group of conglomerates higher up in the sequence is the Commonage Reef which, as far as one is able to judge in this somewhat disturbed locality, occurs at about 100 to 200 feet above the Ada May Reefs. The same faulting which terminates the Ada May Reefs also cuts off the Commonage Reef to the south. The course of the reef to the north-east to where it disappears under surface drift before the main road is reached, is little affected by faulting at the surface. A pebble bed some distance above the Ada May group in the low ground just beyond the spruit north of the railway probably represents its further extension in this direction. The Commonage Reef, which appears to be more constant than the other conglomerates in this group of quartzites, usually occurs in the form of two or three bands of conglomerate over a variable width probably not exceeding six feet. They are separated from one another by a coarse, often gritty, quartzite, which in places carries scattered pebbles. Each conglomerate band is subject to changes in thickness from a pebble line to about two feet thick. The average size of the well rounded pebbles is between one and two inches long, but larger pebbles up to three inches long and more are fairly common.

The Westerly Dipping Quartzites.—From the eastern part of Elandsheuvel No. 54 a belt of quartzites (No. 36 in the columnar sections) resting unconformably on the large mass of quartzites described above and always bounded on the west by Ventersdorp amygdaloid, extends into the Townlands to the vicinity of the railway station. From there it is displaced along an oblique fault (see Fig. 2) to about 150 yards due east of the old Commonage mine. From this point it trends southwards for nearly two miles before it is again cut off by an oblique fault and the whole repeated about 2,000 yards farther to the east on the Townlands. This repeated portion stretches from the railway to the vicinity of the old Niekerk mine, where it disappears under alluvium in low ground. It reappears, along with the underlying quartzite, for the last time in a small inlier in the south-eastern corner of Strathmore No. 15 south of the Niekerk mine.

The Gold Estate Reef.—The quartzite forming this band is a moderately hard rather dull weathering medium- to coarse-grained rock more or less micaceous in parts and containing grit bands, scattered pebbles and conglomerates. At the base of the quartzite there is a very conspicuous conglomerate, the Gold Estate Reef, which is characterized by the large size of its constituent pebbles. The Gold Estate Reef varies in thickness, abruptly in places, from about eighteen feet down to six inches. Over a short distance just north of the spruit the conglomerate seems to be absent altogether, but further north on Elandsheuvel No. 54 it is again strongly developed. The pebbles are mostly of dark and light quartz; quartzite and chert pebbles, the latter frequently banded, are also present while occasional pebbles of some dense greenish rock and of a shaly rock are met

with. In size the pebbles range from less than an inch up to six inches long, while individuals of 8 inches long and more are not uncommon. Generally the pebbles tend to increase in size from the top to the bottom of the conglomerate. They are mostly well smoothed and rounded and a flat round or discoidal shape is not uncommon among the larger individuals. Such pebbles lie with their flat surfaces parallel to the bedding plane. In places the conglomerates is one mass of closely packed pebbles, but elsewhere quartzite partings may appear or the pebbles become more dispersed in a coarse gritty matrix. A unique feature of the Gold Estate Reef is the occasional presence in it of greenish-coloured diamonds, first discovered when the reef was worked for its gold content.

Over a short distance above the Gold Estate Reef scattered pebbles, pebble washes or thin inconstant conglomerates may appear, but in the rest of the quartzite these are rarely present. The contact of the quartzite with the Ventersdorp amygdaloid above is generally concealed under surface drift, but where these rocks do approach one another closely or practically meet, as on both sides of the northern boundary of the Commonage and just south of the railway a little more than two miles east of Klerksdorp, the presence of a narrow strip of dark purplish weathering grit or quartzitic rock is revealed which carries a few scattered pebbles or develops into a thin inconstant small pebble conglomerate. No sign of the presence of a volcanic tuff or breccia between the quartzite and amygdaloid could be found anywhere on the surface of the ground. On the fresh surface the dark gritty or pebbly rock has a dense greenish grey matrix in which glassy quartz grains are either abundant or sparsely scattered. Occasional pebbles or grit grains are also formed of this greenish matter. The other pebbles are of the usual quartz and quartzite, but in addition there are some of the reddish and greyish shaly rock and occasional individuals which show a concentric arrangement as, for example, a cherty pebble with a quartz periphery. These may represent amygdales derived from a decomposed lava.

Correlation of the Quartzites on the Commonage.—Both quartzites of the Klerksdorp Commonage, as far as one is able to judge by their lithological characters and their position relative to the Lower Witwatersrand beds to the north, appear to belong to the upper division of the Witwatersrand System. The lower of the two quartzites, a large mass which, according to that part of it which is exposed at the surface, can hardly be less than about 3,000 feet thick, might possibly be correlated with the Main Bird Series, whereas the other quartzite, resting unconformably on it in a manner possibly similar to the Elsburg quartzites overlapping on to earlier beds at Langermans Kop in the Central Rand, could be included in the Elsburg Series. The greenish grey matter in the matrix of the dark grit or pebble band just described which marks the topmost portion of the latter quartzite, can indicate an intimate mingling of volcanic matter and ordinary sediment before consolidation, and one is reminded of similar-looking rocks at or also close to the contact of the Elsburg and Ventersburg rocks in the Rand and Heidelberg areas where the relationship between the two formations is generally that of a conformable sequence. Should the Klerksdorp occurrence therefore likewise mark the top and signify a conformable passage of the Gold Estate Reef quartzite, i.e. of the Elsburg Series, up into the lavas, then this series

in the Klerksdorp area with a maximum thickness of about 600 feet only forms a marked contrast to the strong development of its equivalent on the Rand and in the Parys-Vredefort area. It must be remembered, however, that the divisional plane separating the Witwatersrand and the Ventersdorp System is defined by a change in lithological character, and that there is no means of discovering whether the volcanic material began to be deposited at the same time in the various regions where these rocks occur. It is possible, or rather probable, therefore, that the boundary necessarily used for mapping is drawn at different horizons at different places, so that changes in the thickness of the underlying quartzite are likely to occur as a result. In the exposure on the Klerksdorp Commonage, however, there is some doubt as to whether the outflow of lavas followed immediately on the deposition of the quartzite before its complete consolidation and subsequent tilting. For reasons already advanced on page 30 it seems likely that the Ventersdorp lava is unconformable to the Gold Estate Reef or Elsburg quartzite in the same way that it is unconformable to the rest of the Witwatersrand beds exposed in the Klerksdorp-Ventersdorp country, and, as indicated in the ideal section of Fig. 3 the possibility exists that the thickness of the quartzite may be appreciably in excess of the maximum thickness exposed on the surface of the ground.

Summary and Correlation of Reefs.

Briefly stated, it was found, that, due to the lack of any confirmatory evidence such as an unbroken sequence from the top of the Government Reef Series to the base of the Upper Witwatersrand division, or the presence of an argillaceous group which could confidently be correlated with the Kimberley Shales, the correlation of the Commonage-Ada May Reefs quartzite group with the Main-Bird Series, and the Gold Estates Reef quartzite with the Elsburg Series can only be tentative. The Main Reef horizon or the equivalent of this group of auriferous conglomerates has not yet been discovered in the Klerksdorp area, and remains therefore an unknown factor. As regards the Lower Witwatersrand beds of the Klerksdorp-Ventersdorp area, their subdivision and correlation with the beds constituting the typical section of the formation in the Central Rand is shown in the columnar sections, Fig. 5. Finally the conglomerates of the Klerksdorp area, which attracted attention because of their gold content, may be classified as follows:—

Transvaal System.

Machavie, Southleigh, Westleigh, Eastleigh, Warren Hill, Wall Rose, Ariston and Niekerk Reefs; reef in mynpacht on central part of Katdoornbosch No. 127; reefs on north-eastern portion of Palmietfontein No. 70 east of Ventersdorp; reef worked in past first by the Mooi River Prospecting and Developing Syndicate and later by the Primus Gold Mines, Limited, on Dryland No. 132.	Black Reef Series.

Upper Division of the Witwatersrand System.

Gold Estate Reef and the westerly dipping large pebble reef of the Southern Klerksdorp Gold and Diamond Company.	Elsburg Series (?).
Ada May Reefs, Commonage Reef, the easterly dipping small pebble conglomerate of the Southern Klerksdorp Gold and Diamond Company, and the reef worked in the Charles Scott Mynpacht on Strathmore.	Main Bird Series (?).

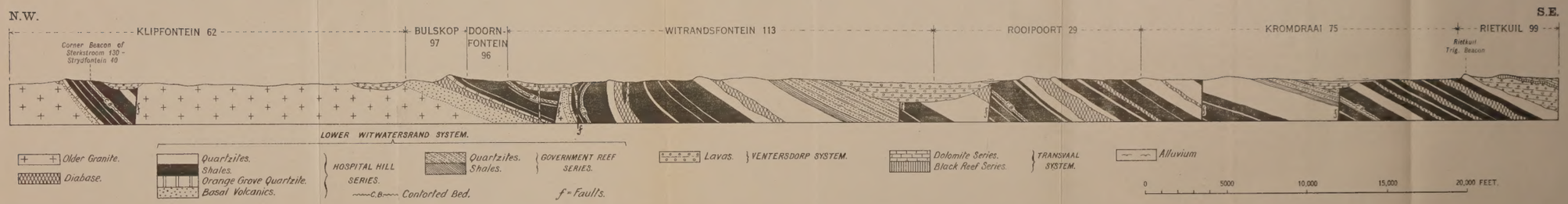
Lower Division of the Witwatersrand System.

Conglomerate reef on eastern bank of spruit on central part of Palmietfontein No. 29 of the Buffelsdoorn Consolidated G.M. Co., Ltd.; "Inner Basin Reefs" opened up by the Afrikander Leases, Ltd.	Jeppestown Series (?).
Buffelsdoorn or White Reef, conglomerate reefs in and around the old Pope's mine on Elandsheuvel No. 54, reefs worked by the Afrikander and Rietkuil mines, Elandslaagte reefs and reefs in the north-western corner of Wolverand No. 55 above broad shale band.	Government Reef Series: Upper Section.
Red Reef, reef on north-western part of Kafferskraal No. 36, and reef along south-eastern boundary of Schoemansfontein No. 28. West Bonanza Reef?	Government Reef Series: Lower Section.

A small pebble conglomerate was opened up in some pits and trenches close to the Benekraal No. 34—Witpoort No. 95 boundary, about a mile west of Schoon Spruit. This conglomerate occurs in the topmost band of the Hospital Hill quartzite.

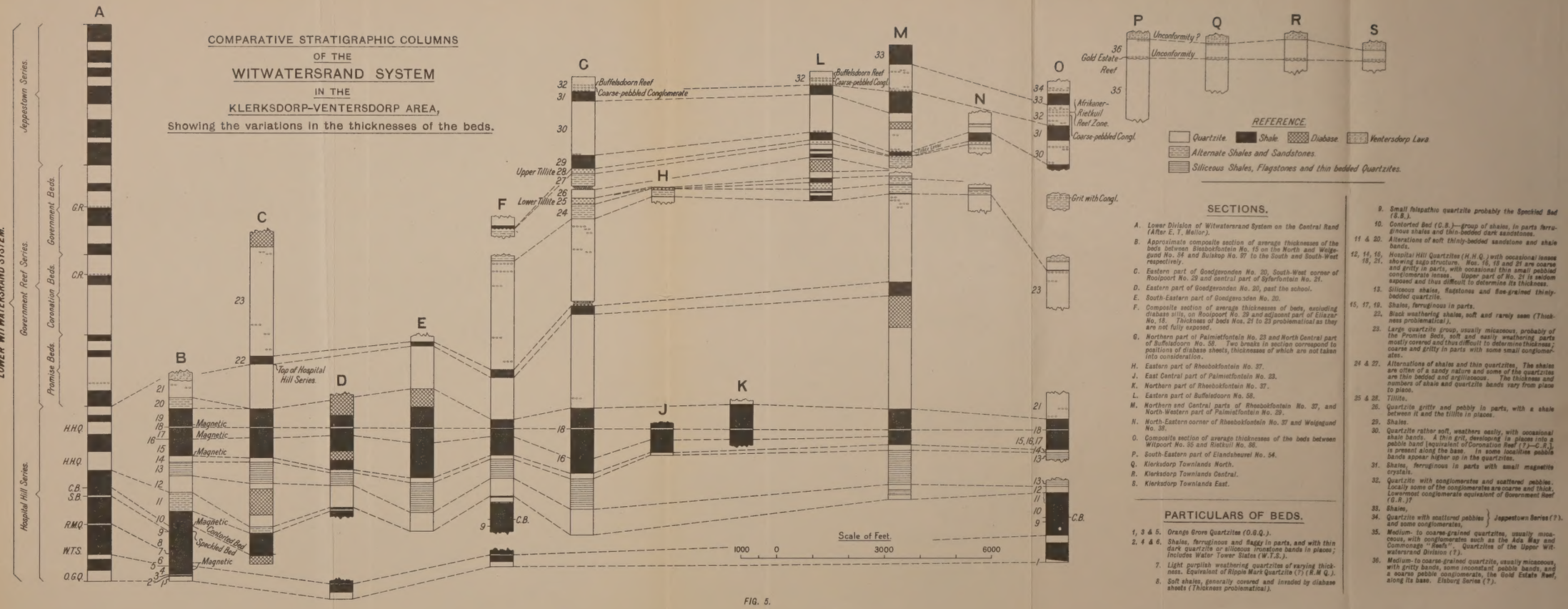
The Dominion Reefs are not correlated here as the area in which they occur has not been mapped yet.

SECTION ACROSS THE STRATA ABOUT MIDWAY BETWEEN VENTERSDORP AND KLERKSDORP.



The Ventersdorp volcanic rocks were probably extruded from channels or fissures coinciding with some of the faults shown in the Section.

FIG. 1.



SECTIONS.

A. Lower Division of Witwatersrand System on the Central Rand (After E. T. Mellor).

B. Approximate composite section of average thicknesses of the beds between Biesbokfontein No. 15 on the North and Welgegund No. 54 and Bulskop No. 97 to the South and South-West respectively.

C. Eastern part of Goedgevonden No. 20, South-West corner of Roolpoort No. 29 and central part of Syferfontein No. 21.

D. Eastern part of Goedgevonden No. 20, past the school.

E. South-Eastern part of Goedgevonden No. 20.

F. Composite section of average thicknesses of beds, excluding diabase sills, on Roolpoort No. 29 and adjacent part of Eliazar No. 18. Thickness of beds Nos. 21 to 23 problematical as they are not fully exposed.

G. Northern part of Palmietfontein No. 23 and North Central part of Buffelsdoorn No. 58. Two breaks in section correspond to positions of diabase sheets, thicknesses of which are not taken into consideration.

H. Eastern part of Rheebokfontein No. 37.

J. East Central part of Palmietfontein No. 23.

K. Northern part of Rheebokfontein No. 37.

L. Eastern part of Buffelsdoorn No. 58.

M. Northern and Central parts of Rheebokfontein No. 37, and North-Western part of Palmietfontein No. 29.

N. North-Eastern corner of Rheebokfontein No. 37 and Welgegund No. 38.

O. Composite section of average thicknesses of the beds between Witpoort No. 35 and Rietkuil No. 36.

P. South-Eastern part of Elandsheuvel No. 54.

Q. Klerksdorp Townlands North.

R. Klerksdorp Townlands Central.

S. Klerksdorp Townlands East.

PARTICULARS OF BEDS.

1, 3 & 5. Orange Grove Quartzites (O.G.Q.).

2, 4 & 6. Shales, ferruginous and flaggy in parts, and with thin dark quartzite or siliceous ironstone bands in places; Includes Water Tower Slates (W.T.S.).

7. Light purplish weathering quartzites of varying thickness. Equivalent of Ripple Mark Quartzite (?) (R.M.Q.).

8. Soft shales, generally covered and invaded by diabase sheets (Thickness problematical).

9. Small felspathic quartzite probably the Speckled Bed (S.B.).

10. Contorted Bed (C.B.)—group of shales, in parts ferruginous shales and thin-bedded dark sandstones.

11 & 20. Alterations of soft thinly-bedded sandstone and shale bands.

12, 14, 16, 18, 21. Hospital Hill Quartzites (H.H.Q.) with occasional lenses showing sago structure. Nos. 16, 18 and 21 are coarse and gritty in parts, with occasional thin small pebbled conglomerate lenses. Upper part of No. 21 is seldom exposed and thus difficult to determine its thickness.

13. Siliceous shales, flagstones and fine-grained thinly-bedded quartzite.

15, 17, 19. Shales, ferruginous in parts.

22. Black weathering shales, soft and rarely seen (Thickness problematical).

23. Large quartzite group, usually micaceous, probably of the Promise Beds, soft and easily weathering parts of Buffelsdoorn No. 58. Two breaks in section correspond to mostly covered and thus difficult to determine thickness; coarse and gritty in parts with some small conglomerates.

24 & 27. Alternations of shales and thin quartzites. The shales are often of a sandy nature and some of the quartzites are thin bedded and argillaceous. The thickness and members of shale and quartzite bands vary from place to place.

25 & 28. Tillite.

26. Quartzite gritty and pebbly in parts, with a shale between it and the tillite in places.

29. Shales.

30. Quartzite rather soft, weathers easily, with occasional shale bands. A thin grit, developing in places into a pebble band [equivalent of Coronation Reef (?)—C.R.], is present along the base. In some localities pebble bands appear higher up in the quartzites.

31. Shales, ferruginous in parts with small magnetite crystals.

32. Quartzite with conglomerates and scattered pebbles. Locally some of the conglomerates are coarse and thick. Lowermost conglomerate equivalent of Government Reef (G.R.)?

33. Shales, } Jeppestown Series (?).

34. Quartzite with scattered pebbles } and some conglomerates.

35. Medium- to coarse-grained quartzites, usually micaceous, with conglomerates such as the Ada May and Commonage "Reefs". Quartzites of the Upper Witwatersrand Division (?).

36. Medium- to coarse-grained quartzite, usually micaceous, with gritty bands, some inconstant pebble bands, and a coarse pebble conglomerate, the Gold Estate Reef, along its base. Elsburg Series (?).

FIG. 5.